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Experiments were conducted to examine the detection and identification of complex visual patterns, representing various underwater sounds, in terms of stimulus dimensions indicated by a psychological scaling analysis of similarity judgments. Psychological dimensions differed somewhat between naive and experienced observers, and between visual and auditory representations, but high correlations with physical dimensions were found in all cases. A second objective of the study was to relate identification to

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detection, over successive stages of relatively long signals. The ROC analysis developed for detection of signals in random noise was applied to discrimination of wanted and unwanted signals. The analysis of stimulus dimensions enabled qualitative predictions of the relative levels of detection and identification for different sets of wanted and unwanted signals. The "joint" ROC, based on the probability of correct detection *and* correct identification, provided quantitative benchmarks for these predictions.

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Although this paper describes a perceptual analysis of visual patterns, its main conceptual antecedents are perceptual analyses of complex sounds. Most directly in line are a study of the identification of synthetic, arbitrary sounds (Webster, Woodhead, and Carpenter, 1973), a multidimensional scaling analysis of a set of sounds similar to those used by Webster, et al (Howard and Silverman, 1976), scaling analyses of the sounds constructed by Webster, et al and of the visual transforms of those sounds (Morgan, Woodhead, and Webster, 1976), and a scaling analysis of real (underwater) sounds (Howard, 1976). The scaling analyses by Howard and by Howard and Silverman were based on observers' judgments of the degree of stimulus similarity; the scaling analysis by Morgan, et al was based on measures of stimulus similarity derived from numbers of confusions in an identification task.

We have examined the identification of visual representations of a set of underwater sounds similar to those

used by Howard, and also the multidimensional scaling of those stimuli based on judgments of degree of similarity. We have attempted to gain understanding of the fundamental process--identification--in terms of the distinctive features or dimensions of the stimuli as revealed by the psychological scaling analysis. In particular, we have tried to predict certain aspects of identification performance from the dimensional analysis based on similarity judgments.

Other objectives of the present study have been to relate signal identification to signal detection, and to do so over successive stages of observation of relatively long signals. A companion paper (Swets, Green, Getty, and Swets, 1977) shows how a "joint" Relative Operating Characteristic (ROC) for detection plus identification can be predicted from the simple detection ROC, drawing on a model proposed by Starr, Metz, Lusted, and Goodenough (1975). The main assumptions of this model are that the signals are orthogonal and of equal energy. The companion paper argues also for the importance of analyzing the growth in perceptual accuracy over time, on the grounds that temporal integration of sensory information is fundamental to detection and identification. Adaptive changes in the sensory analysis may also occur over time (see,e.g., Swets and Birdsall, 1978).

Partially motivating the experiments reported here is the task of the sonar observer who must detect and identify complex underwater sounds or visual representations of them. The need to analyze temporal integration in this case is obvious: both detection and identification relative to a given observation (or a given stimulus) proceed in slow motion, being measured in minutes, and often being broken down into discrete stages of observation. One reason for a long observation period is that redundant signal information serves to reduce the interference of random noise. Another is that information in underwater acoustic events often inheres in the syntactic pattern of a string of primitive sounds.

Another basic characteristic of the sonar problem is that the signal patterns are not orthogonal, but highly correlated. Moreover, the interfering noise is far from random, and, indeed, often appears in distinctive patterns similar to signal patterns. In fact, the definition of "signal" and "noise" differs from one sonar task to another depending upon whether the observer is looking for, or trying to ignore, a particular source of sound: surface ships, submarines, airplanes, rain squalls, schools of fish, variations in ocean depth, and so forth.

Our visual representations of eight real underwater sounds are described in detail in the next section. Here we point out that, in our detection-and-identification task, we defined a particular four of these visual patterns as signals--a different set of four in each of three experimental conditions--and presented them along with the other four which served as noise. A detection response was followed by an identification response; only the four alternatives defined as signals were available as identification responses. Such a task structure permits extension of a detection analysis in terms of the ROC, from situations in which weak signals are masked by random noise to situations in which strong signals are confused with strong "noise" patterns that closely resemble them. Both situations are represented in ordinary perception as well as in sonar observing: sometimes one detects weak signals in random noise, and at other times one distinguishes between strong "wanted" signals and strong "unwanted" signals.

PROCEDURE

Scaling Procedure

The Stimuli. Howard (1976) selected eight recordings of underwater sounds to represent a range of common natural and

mechanically produced sounds. They were referred to as (1) Sheet Cavitation (SC), (2) Biologics (BI), (3) Compressed Cavitation (CC), (4) Torpedo (TO), (5) Diesel Engine (DE), (6) Rain Squall (RS), (7) Steam Noise (SN), and (8) Flutter (FL). Their long-term spectra are shown in Fig. 1.

Howard's physical and psychological analyses indicated that the top four stimuli in the figure tended to have bimodal spectra while the bottom four tended toward unimodal spectra. The left-most four stimuli were seen to be negatively skewed (less low-frequency information) while the right-most four were more nearly symmetrical. Finally, not evident in the figure, BI and FL had a definite low-frequency temporal periodicity.

For our visual stimuli we converted the spectra of these eight stimuli to steady horizontal brightness profiles (the greater the energy, the darker the trace), thus maintaining to some extent the first two dimensions of the auditory stimuli. We converted periodicity to a pulsing (or striation) in the vertical dimension, because the stimuli in our detection -and-identification experiment (described shortly) developed over time along the vertical dimension. Specifically, we grouped (1) SC and (2) BI with (7) SN and (8) FL by giving all four relatively low-frequency periodicities, and gave the remaining

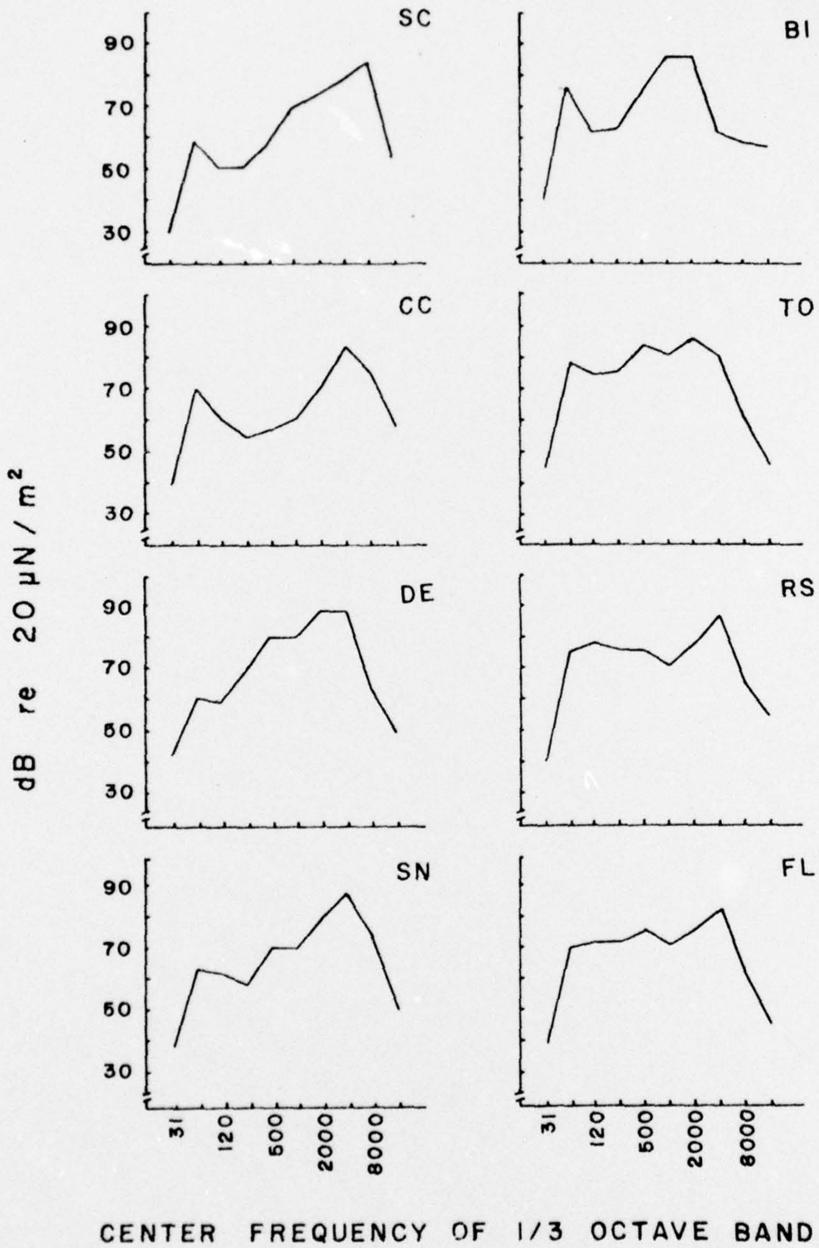

Figure 1. Long-term spectra of eight underwater sounds (From Howard, 1976).

(middle) four relatively high-frequency periodicities. In particular, the pulses per stimulus were 15, 16, 17, and 18, for Stimuli 1, 2, 7, and 8, respectively, and 21, 22, 23, and 24, for Stimuli 3, 4, 5, and 6, respectively. The resulting stimuli are shown in Fig. 2.

The stimuli were constructed on a COMTAL model 8000-SA image-processing system, driven by a DEC PDP-11/34 minicomputer, and displayed in an area 24 cm wide x 12 cm high on a CONRAC 17-inch (43 cm) SNA television monitor. It can be seen in Fig. 2 that we added a background of random noise to each patterned stimulus. The noise consisted of a 256 x 128 matrix of elements, each having an independent gray value sampled from a Gaussian distribution with mean 128 units and standard deviation 10 units on the 256-unit COMTAL gray scale.

Each of the eight patterned stimuli was constructed by subtracting from the noise background a horizontal brightness profile corresponding to the long-term spectrum of each of the signals shown in Fig. 1. Thus, increasing energy in the spectrum resulted in a darker trace. All signal profiles were scaled to have the same space-average darkness of 20 gray units below the mean gray value of the noise background. In addition, the darkness of each point in the signal profile was sinusoidally

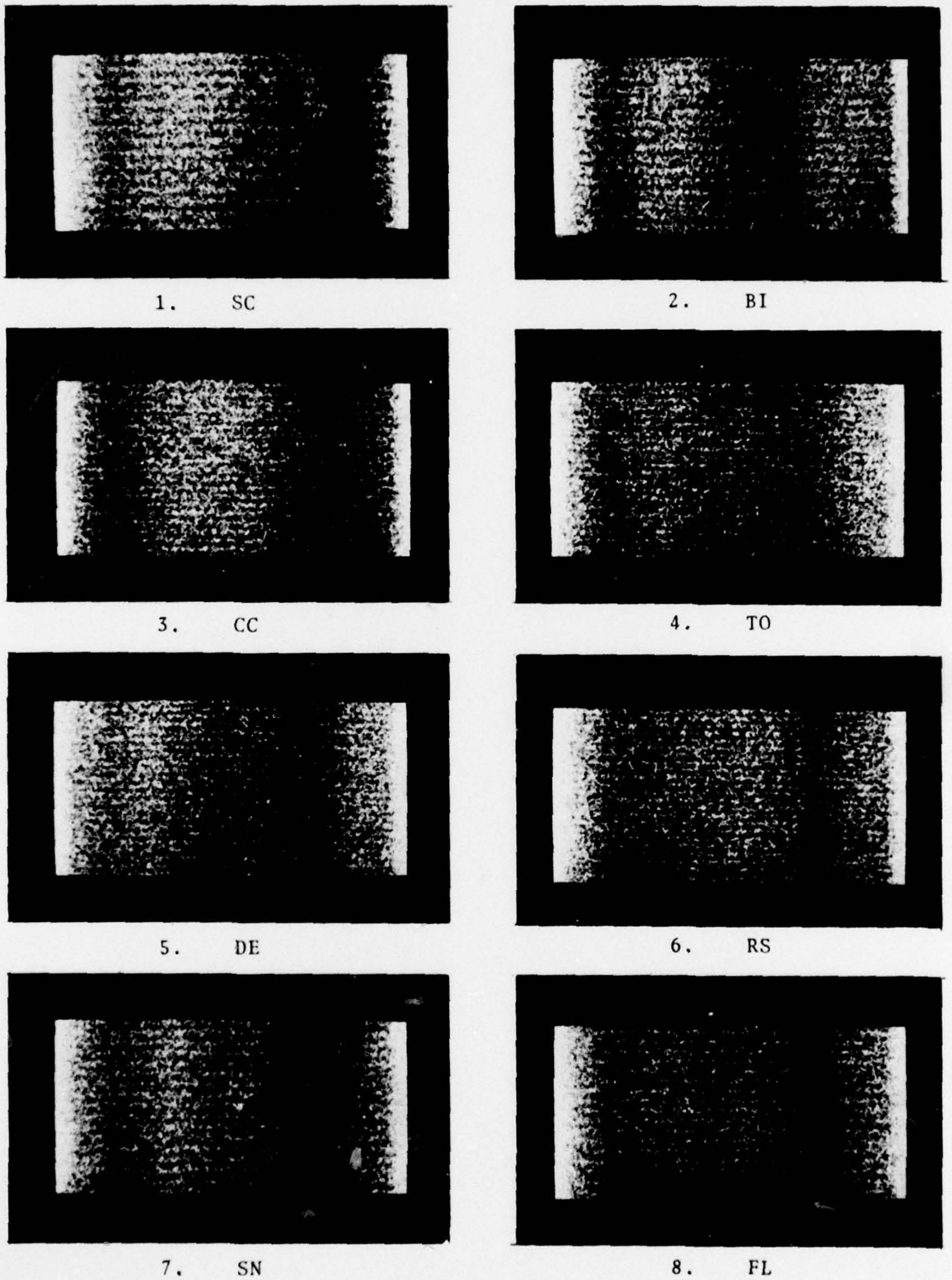

Figure 2. Visual representations of the eight underwater sounds, photographed from the display monitor.

varied in the vertical dimension, with a peak-to-peak brightness variation of 200 percent about the steady-state value.

For the similarity judgments, the stimuli displayed on the television monitor were photographed and presented to groups of four judges by means of 35 mm slides. The projection screen was approximately 5 meters from the judges; each stimulus subtended a visual angle of about 3.5 degrees.

Similarity Judgments. Pairwise judgments of similarity were elicited from 20 members of BBN's technical staff, selected in the main to be no more than casually familiar with stimuli of the type we constructed. Such judgments were also obtained from the three observers employed in the detection-and-identification task, after they had completed that task.

After seeing the eight stimuli presented successively, twice, for 15 seconds each, the judges rated similarity on a 10-point scale for the 28 possible pairs, with members of each pair presented side-by-side for 15 seconds; the following response interval was also 15 seconds. To assess response consistency, the 28 pairs were then presented a second time, with left-right positions reversed, and in a different random order--to the naive judges--and a second and third times to the three experienced observers.

Analyses. The INDSCAL multidimensional scaling procedure (Carroll and Chang, 1970) was applied to the similarity judgments, in order to determine the stimulus dimensions or distinctive features that lay behind the judgments. A physical analysis of the stimuli was also conducted.

Detection-and-Identification Procedure

Stimulus Pattern and Noise Parameters. The stimulus patterns used in the detection-and-identification task were presented with certain parameters different from those used in the scaling task, in order that errors of detection and identification would occur. Specifically, the standard deviation of the background noise distribution was increased from 10 to 15 gray units, and the depth of modulation (peak to peak) of the signal profiles along the vertical dimension was decreased from 200 to 60 percent. The CONRAC monitor was adjusted so that the middle gray (128) units) corresponded to a luminance of about 62 cd/m^2, and the full white (255 units) corresponded to a luminance of about 308 cd/m^2.

Viewing Environment. Observers sat approximately two meters from the stimulus-display screen. This screen was about one meter from the floor, and viewed comfortably over the CRT/keyboard computer terminals (Lear Siegler ADM-3A) used for

response cueing and response entry. Ambient room lighting was approximately 3 cd/m^2.

Stimulus Presentation. Four of the eight patterns were designated as signals in each condition of the experiment. Signals were presented at random on one-half of the trials, with each signal equally likely. The noise patterns were presented, all equally likely, on the remaining trials. The observers were given high-contrast Polaroid pictures of the four signals (similar to those represented in Fig. 2) for reference as they chose.

Each trial contained five stages of observation, with each stage followed by the responses described below. A stage consisted of painting a horizontal stripe over approximately one-tenth of the screen, about one-quarter of the distance down from the top of the screen. Following stages "pushed" preceding stages downward in "waterfall" fashion.

Responses. The first response made at each stage was a detection response in the form of a six-category rating of confidence. Then an identification response was made, no matter which detection response was made previously.. The identification response was a numeral--1, 2, 3, or 4--in accordance with their assignment to the signals. Responses were

made via the keyboard of the CRT terminal, with appropriate time and type of response cued by the terminal's display; the complete terminal display is shown in Fig. 3.

Trial and Session Timing. A tenth of the screen (one stage of observation) was painted in eight seconds. The next tenth was painted after all observers had completed their responses. The response interval lasted approximately five seconds, followed by a warning sound that the next stage would occur. Feedback was given at the conclusion of a trial (five observation stages), and 1.5 seconds intervened between trials.

Ten trials were presented in a block, and six blocks were presented in a two-hour session. Fifteen sessions were conducted over three weeks. Certain sessions or initial parts of sessions were designated as practice, and not included in the analyses.

Experimental Control. Stimulus presentation and trial timing were controlled, responses were recorded, and data were analyzed by the PDP-11 computer.

Observers. Three observers were members of BBN's technical staff, including one of the experimenters (JBS).

Experimental Conditions. In Condition 1, the four signals were Numbers 1, 2, 5, and 6, of Fig. 2. According to the

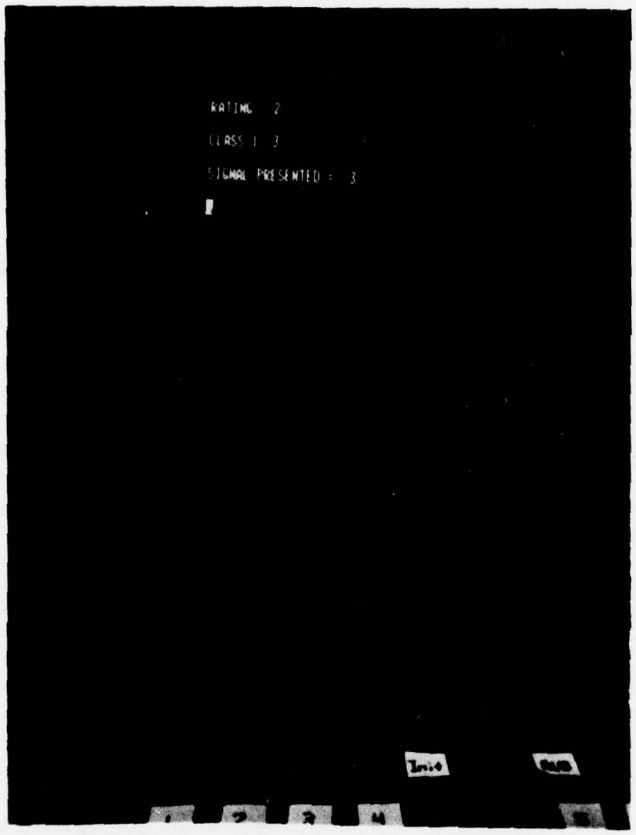

Figure 3. An example of the complete terminal display at the end of a trial.

three-dimensional analysis given with Figs. 1 and 2, these signals were not distinguished from the four noise patterns by any single dimension. In Howard's terms, Numbers 1 and 2 are bimodal while 5 and 6 are unimodal; Numbers 1 and 5 are skewed while 2 and 6 are symmetrical. In our terms, Numbers 1 and 2 are pulsed with relatively low frequencies while 5 and 6 have higher-frequency periodicities.

In Condition 2, the designated signals were Numbers 3, 4, 5, and 6 of Fig. 2. They were the four patterns with relatively high frequencies of periodicity.

In Condition 3, the signals consisted of the group characterized as relatively skewed: Numbers 1, 3, 5, and 7.

RESULTS

Physical Analysis

We considered using in our physical analysis Howard's steady-state dimensions of bimodality/unimodality and skewness/symmetry, and his measurements of the dimensions so named. As mentioned, we altered his stimuli relative to periodicity, and had our own physical measures for that dimension.

We recognized, however, as the work of Morgan, et al suggests, that the visual transformations of the sounds could make somewhat different dimensions salient. A look at the visual patterns in Fig. 2 suggests, for example, that a trimodality/bimodality dimension might be more evident in them than the bimodality/unimodality dimension found in the sounds. Moreover, fewer visual patterns appear symmetrical. Again, it would seem that the amount of light-dark contrast within a visual pattern would be a relevant dimension.

So we devised new measures for four physical dimensions, ϕ_1 to ϕ_4. The first measure is termed "low-frequency energy," and is a measure of the amount of energy in Howard's second and third filter bands. As indicated in Fig. 1, these are the 1/3-octave bands with center frequencies of 63 and 125 Hz. This measure, it can be seen, bears a relation to the "skewness" that Howard noted in his sounds. The left-hand column of stimuli (Fig. 1) tends toward lower amounts of low-frequency energy. Our second physical measure is "mid-frequency energy"--the energy in the fifth and sixth bands of Fig. 1, i.e., the bands with center frequencies of 500 and 1000 Hz. Our physical measure denoted ϕ_3 is a measure of "contrast," and more specifically, of the depth of the "primary white trough"--defined as the average deviation between the points on the energy profile (Fig. 1) and a line

connecting the two local maxima bounding the primary trough. This dimension, it may be noted, is correlated with Howard's bimodality; the upper four stimuli in Fig. 1 tend to show the most contrast. The measure ϕ_4 is "periodicity," with pulses per stimulus as listed in the Procedure section.

The measures we used were selected to represent well the dimensions we experimenters saw in the stimuli, and, as will be seen, to correlate highly with the psychological dimensions revealed by the INDSCAL perceptual scaling analysis as applied to the experienced observers. The various values of the eight stimuli on the four physical dimensions are listed in Table I. (The stimuli are not ranked in the table on the first three dimensions in exactly the way they would have been if based directly on Fig. 1, because, as mentioned earlier, the signal profiles of Fig. 1 were normalized in our visual transformations to have the same space-average darkness.)

Stimulus	Physical Dimensions ϕ_1	ϕ_2	ϕ_3	ϕ_4	Psychological Dimensions ψ_1	ψ_2	ψ_3
1. SC	90	104	8.8	15	-.405	.427	.229
2. BI	103	121	10.5	16	.441	-.143	.675
3. CC	104	93	12.8	21	-.552	-.209	.243
4. TO	107	116	4.5	22	.380	-.083	-.344
5. DE	87	118	4.5	23	.317	.597	-.213
6. RS	110	105	5.5	24	-.154	-.521	-.233
7. SN	96	108	6.0	17	-.198	.207	.097
8. FL	107	110	4.5	18	.171	-.276	-.454

Table I. Physical coordinates for each of the eight stimulus patterns, and psychological coordinates yielded by the three experienced observers.

Scaling Analysis--Experienced Observers

We submitted to INDSCAL analysis the third set of 28 similarity judgments made by the experienced observers. Though the first and second, and second and third, sets of judgments showed a correlation greater than 0.50 for each observer, the correlation of the first and third sets was less than 0.50 for two of the three observers. This result suggests that the bases for the judgments was changing gradually over the course of the three sets, and consequently, the INDSCAL analysis was applied only to the last of the three sets of judgments.

The proportion of variance accounted for by the solutions with one to four dimensions is given by the open circles in Fig. 4. The weights of the eight stimuli in the three-dimensional solution are listed as ψ_1 to ψ_3 in Table I.

Table II shows the product-moment correlations of the physical variables, ϕ_1 to ϕ_3, with the psychological dimensions ψ_1 to ψ_3. There is a clear physical correlate--an r in the vicinity of 0.90--for each of the three perceptual dimensions. Correlations greater than 0.83 have a probability less than 0.01 for a two-sided test. The remaining correlations fall well below 0.71, which has a corresponding probability of 0.05 for a two-sided test.

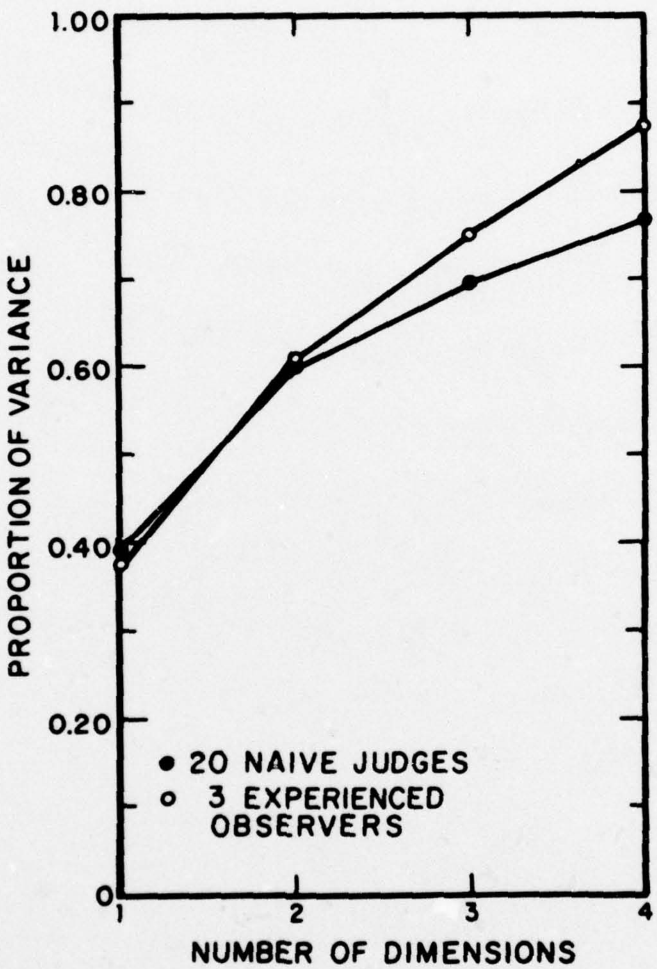

Figure 4. The proportion of variance accounted for by the INDSCAL solution with varying numbers of dimensions, for both naive judges and experienced observers.

	ψ_1	ψ_2	ψ_3	ϕ_1	ϕ_2	ϕ_3
ψ_1		.030	-.189	.095	$\boxed{.947}$	-.491
ψ_2			.118	$\boxed{-.971}$	.246	-.113
ψ_3				-.215	-.037	$\boxed{.827}$
ϕ_1					-.142	.007
ϕ_2						-.475
ϕ_3						

Table II. Product-moment correlations between each of the physical and psychological dimensions, for the experienced observers.

The first psychological dimension corresponds to "mid-frequency energy;" the second, to "low-frequency energy;" and the third, to "contrast." To our surprise, "periodicity" did not emerge as a psychological dimension for our experienced observers. This despite the fact that periodicity was salient for them, as we shall see, in the detection-and-identification task. Indeed, these observers mentioned that while they were aware of the periodicity variable in the judgment of similarity, they did not find it helpful in that task.

Scaling Analysis--Naive Judges

We submitted to INDSCAL analysis the second of the two sets of 28 similarity judgments, for the 14 of our 20 judges whose judgments on trials 11 to 28 of the first set correlated higher than 0.50 with the same pairs in the second set. The idea was to use only the data of judges who were behaving rather consistently.

The proportion of variance accounted for by the solutions with one to four dimensions is given by the closed circles in Fig. 4. The weights of the eight stimuli in the four-dimensional solution are listed as ψ_1 to ψ_4 in Table III, along with the physical coordinates repeated from Table I.

	Physical Dimensions				Psychological Dimensions			
Stimulus	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ψ_1	ψ_2	ψ_3	ψ_4
1. SC	90	104	8.8	15	-.546	.261	-.369	.385
2. BI	103	121	10.5	16	-.083	.403	.616	.575
3. CC	104	93	12.8	21	.262	.595	-.470	-.182
4. TO	107	116	4.5	22	.004	-.264	.358	-.440
5. DE	87	118	4.5	23	-.514	-.098	.276	-.227
6. RS	110	105	5.5	24	.515	-.177	-.130	-.392
7. SN	96	108	6.0	17	.058	-.210	-.170	.300
8. FL	107	110	4.5	18	.305	-.511	-.112	-.019

Table III. Physical coordinates for each of the eight stimulus patterns, and psychological coordinates yielded by 14 naive judges.

Table IV shows the product-moment correlations of the physical measures mentioned earlier, ϕ_1 to ϕ_4, with the psychological dimensions, ψ_1 to ψ_4. There is a clear physical correlate (an r in the vicinity of 0.90) for each of the four perceptual dimensions. Recall that correlations greater than 0.83 have a probability less than 0.01 for a two-sided test. Again, the remaining correlations fall below 0.71, which has a corresponding probability of 0.05 for a two-sided test.

	ψ_1	ψ_2	ψ_3	ψ_4	ϕ_1	ϕ_2	ϕ_3	ϕ_4
ψ_1		-.230	-.224	-.381	$\boxed{.890}$	-.371	-.010	.339
ψ_2			-.133	.378	-.182	-.347	$\boxed{.948}$	-.242
ψ_3				.080	.052	$\boxed{.934}$	-.260	.074
ψ_4					-.366	.168	.434	$\boxed{-.927}$
ϕ_1						-.142	.007	.280
ϕ_2							-.475	-.053
ϕ_3								-.358
ϕ_4								

Table IV. Product-moment correlations between each of the dimensions, for the naive judges.

The primary result is that the physical measures ϕ_1 to ϕ_3, which were selected to correlate highly with the three psychological dimensions of the three experienced observers, correlate highly as well with the independent set of data obtained from the 14 naive judges. Moreover, the naive judges yield a fourth dimension that corresponds to the physical variable of periodicity.

We asked the judges, after the similarity ratings, to write down the dimensions they were using in those ratings. According to our translation, 12 of the 14 judges listed something related to our first two physical dimensions--having to do with the

relative darkness of vertical bands in different left-mid-right positions. And 13 of the 14 judges listed a variable corresponding to our third physical dimension, "contrast." Six of the 14 judges mentioned a variable related to our fourth dimension, "periodicity. Though "periodicity" was remarked upon by a minority of the judges, it appeared to be quite salient for that minority. These 6 judges had an average weighting of 0.41 on ψ_4 while the remaining judges had an average weighting of 0.11 on that dimension. For that minority, the correlation between original data and computed scores increased an average of 6.7 points in moving from three to four dimensions; for the others the average increase was 1.4 points.

Detection-and-Identification Task

We turn now to a consideration of the detection-and-identification task--first, briefly, on its own, molar, performance terms. Then we attempt to relate certain aspects of this performance to the distinctive features of the stimuli as revealed by the scaling analysis.

<u>Detection and Identification Accuracy Over Time</u>. Figure 5 shows how detection accuracy and identification accuracy grow over the five stages of observation, for the three signal

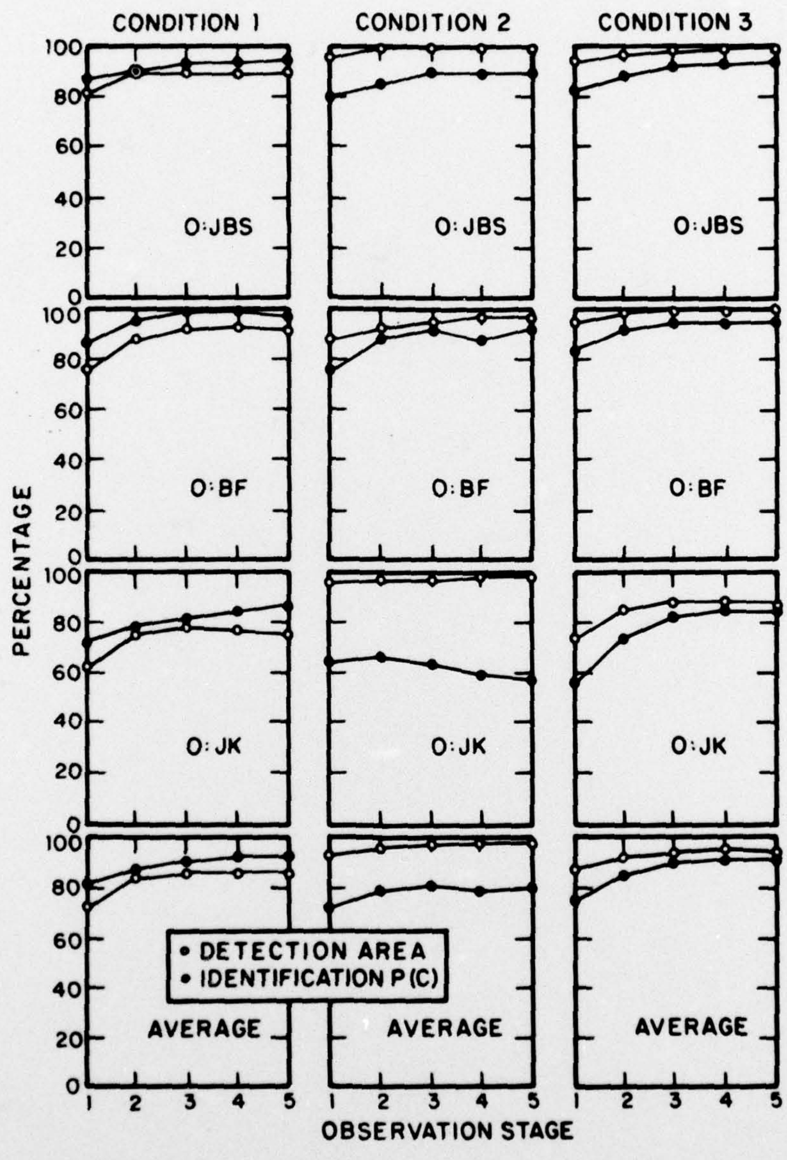

Figure 5. The area under the ROC curve and the percentage of correct responses over observation stages for three observers.

conditions. Detection performance is indexed by the trapezoidal area under the ROC (see Green and Swets, 1966, 1974), and identification performance is indexed by the proportion of correct choices. Each of the points shown is based upon 230 trials.

That the two indices grow apace is consistent with the argument of the companion paper (Swets, Green, Getty, and Swets, 1977) that detection and identification proceed simultaneously as parts of the same process. In the model for the "adaptive optimum receiver" put forth by Nolte (1967), the observer stores updated probability estimates separately for each signal under consideration, so that the basis exists for both detection and identification responses.

<u>Relative Levels of Detection and Identification</u>. Recall that in Condition 1 the signals are not consistently distinguished from the noise patterns on any particular dimension. That is, Numbers 1 and 2 are relatively bimodal, high in contrast, and low in pulse frequency, while Numbers 5 and 6 are the opposite. Again, Numbers 1 and 5 are relatively skewed or low in low-frequency energy while Numbers 2 and 6 are the opposite. Thus, in Condition 1, while detection cannot be based simply on a single dimension, all of the dimensions identified are available for identification.

We might expect then, that in Condition 1, identification, as compared to detection, would be relatively easy. Note, for example, that the observer could determine first that the pattern present is low in low-frequency energy and low in periodicity--he can then confidently and correctly identify it as Number 1 before he is able to detect its difference from (the noise pattern) Number 7, on the basis of "contrast." Let us note, for comparison with the other two conditions, that averaged over observers and observation stages, in Condition 1 the detection index is .83 and the identification index is .89.

Recall that in Condition 2 the dimension of pulse rate was the main basis for detection and of reduced value for identification. Consistent with this difference, identification is more difficult compared to detection. Specifically, the average detection index is .96 and the average identification index is .78. With reference to Condition 1, the detection index is up .13 while the identification index is down .11.

In Condition 3, the signals were four stimuli characterized as relatively skewed, or low in low-frequency energy. Here, the two indices are intermediate between Conditions 1 and 2: the detection index is .93 and the identification index is .86. With reference to Condition 1, detection is up .10 and identification

is down .03. In the present experiment, pulse rate apparently dominates skewness or low-frequency energy as a basis for either detection or identification.

The ordinal prediction of the relative levels of detection and identification performance in the three conditions can be given a quantitative basis by considering inter-stimulus distances in the multidimensional space derived from the scaling analysis. With regard to detection, we may expect that detection of a "signal" will be increasingly difficult, on the average, the smaller the average distance between signal and noise patterns. Thus, we may predict the order of detection performance across the three conditions by calculating the average distance between the 16 signal-noise pairs for each condition. As a reasonable first approximation to an average observer, distances were calculated weighting the three dimensions derived from the scaling analysis equally, and adding periodicity as a fourth dimension, weighted equally with the others. The average distances obtained for the three conditions were 0.89, 1.03, and 0.93, respectively. These distances agree ordinally with the detection probabilities 0.83, 0.96, and 0.93 obtained for the three conditions, respectively.

With regard to identification, we may expect that correct identification of the four signals will be increasingly difficult, on the average, the smaller the average inter-signal distance. Values of this measure, obtained for each condition by averaging the six inter-signal distances, are 1.24, 0.77, and 0.88 for the three conditions, respectively. Again, these distances agree ordinally with the identification probabilities 0.89, 0.78, and 0.86 obtained for the three conditions, respectively.

Thus, the dimensional information about the set of stimulus patterns provided by the scaling analysis successfully predicts the relative performance levels of both detection and identification when different subsets of the patterns are designated as "signals."

Predicting Identification from Detection. Our present signals obviously violate an important assumption--namely, orthogonality-- of the model proposed by Starr, Metz, Lusted, and Goodenough (1975) to predict a joint ROC for detection-plus-correct-identification from the simple detection ROC. So we would not expect the predictions of the model to hold up as well in general for these signals as they did for the simpler signals described in our companion paper (Swets, Green,

Getty, and Swets, 1977). However, our three sets of signals differ with respect to the extent of their departure from orthogonality: the signals of Conditions 2 and 3 each have something in common (pulse rate and amount of low-frequency energy, respectively), whereas the signals of Condition 1 were selected to have no common denominator. Therefore, a comparison across conditions, of our observers' performance with the performance predicted by the model, may be instructive.

In Condition 1, in which identification is relatively easy, the performance values obtained consistently exceed the predicted values--on the average, by 3.8, 8.7, and 4.3 points for the three observers, respectively. (The obtained and predicted values are averaged over six ROC points for each of five stages of observation.)

On the other hand, in Condition 2, in which identification is harder compared to detection, the values obtained are consistently lower than the ones predicted--on the average by 12.2, 36.2, and 3.8 points for the three observers.

In Condition 3--yielding intermediate results on the relative difficulty of detection and identification, but more like Condition 2 than Condition 1--the values obtained are again lower than the ones predicted--by 7.3, 7.6, and 6.9 points for the three observers.

These results suggest to us the possibility that the model of Starr, et al will contribute a helpful quantitative aspect to the study of the relative difficulty of detection and identification. In the present paper we have used the dimensional analysis merely to order our three different signal-noise conditions; the prediction of the model of Starr, et al provides a quantitative benchmark that may be useful in evaluating any given combination of signal and noise patterns.

SUMMARY AND DISCUSSION

This paper describes two *approaches* to increased understanding of the process of stimulus identification. In one of them we have attempted to relate signal identification to signal detection. In this regard our experiments incorporated two aspects of realism: the fact that the detection and identification processes proceed together over time; and the fact that detection may be a matter of discriminating wanted and unwanted signal-like patterns, rather than signals from random noise. In the latter connection, we have observed that the particular properties of the patterns that are of interest for detection and identification, respectively, will vary from one situation to another. It would appear that the simple ROC can be used to evaluate detection performance in this context, and there

is some indication that the joint ROC, which considers identification along with detection and which may be related to the detection ROC, will also be useful here.

The second approach to the stimulus-identification process represented in this paper is based on the multidimensional scaling of the stimuli, as derived from judgments of similarity. We were able to develop physical measures that correlate highly with the psychological dimensions of a first group of judges, which measures were then found to correlate highly with the psychological dimensions yielded by a second, independent group of judges. In a departure from earlier work on perceptual scaling, we have sought to predict identification performance by means of the dimensions that were identified in the scaling analysis. Our results demonstrate that a dimensional analysis, even when applied in a relatively crude fashion, can successfully generate at least some ordinal predictions about how difficult identification will be relative to detection. In a paper to follow (Getty, Swets, Swets, and Green, 1978), we report a finer-grained examination of the ability of dimensional analyses to predict identification performance. In that study, distances separating our eight stimuli that are derived from the multidimensional space based on similarity judgments are used to predict quantitatively, cell-by-cell, a full 8 x 8 confusion

matrix, as well as the truncated matrices obtained from the detection-and-identification task described here.

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